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A PERSONNEL READINESS TRAINING PROGRAM:
OPERATION AND MAINTENANCE OF THE 1200 PSI STEAM PROPULSION PLANT

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Plant. In the present application, the Boiler Technicians from 12 cruisers and destroyers were given a diagnostic pretest and, with the exception of one crew, were retested 3 to 6 months later. Four ships were assigned to each of three experimental groups: (1) a Control Group in which the participants were given feedback on the pretest in terms of an overall percentage score, (2) a Feedback Group in which the members were given an outline indicating their specific weaknesses, and (3) a Feedback + Training Group in which the members were given the same type of information as the Feedback Group but, in addition, were assigned specific remedial training. Diagnostic testing was successful in detecting deficiencies of Fleet personnel on written items related to the operation and maintenance of the 1200 PSI Steam Propulsion Plant. In the pretest sample, of 305 Boiler Technicians only 17 showed no weaknesses. A very small but statistically significant improvement in performance resulted from providing feedback. However, there was little effect of remedial training because only 21 percent of the Boiler Technicians completed their assigned modules. Secondary analyses suggested that, had the assigned training been completed, it would have improved performance. The nonuse of training seems to be due to the excessive time demands associated with the job and, to some degree, the lack of adequate study facilities on board ship; Boiler Technicians who studied ashore completed 42 percent of their assigned training while those who studied on board ship completed only 3 percent.

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FOREWORD

This Advanced Development effort was conducted in support of Project Z0108-PN (ZPN07), Education and Training Development, under the sponsorship of the Chief of Naval Operations (OP-099). This is the fourth in a series of reports relating to Subproject Z0108-PN.24, Personnel Readiness Training. The first report, NPRDC Special Report 75-8, A Personnel Readiness Training Program: Initial Project Developments, provided an overview of the project. Subsequent reports, NPRDC Technical Report 77-4, A Personnel Readiness Training Program: Operation of the AN/BQR-20A, and NPRDC Technical Report 77-19, A Personnel Readiness Training Program: Maintenance of the Missile Test and Readiness Equipment (MTRE Mk 7 MOD 2), described the program application for the submarine Sonar Technician and Missile Technician, respectively. A final report will summarize findings and conclusions across all three applications.

In this application, Boiler Technicians used training materials covering basic mechanical skills and knowledges. These materials were developed by the Propulsion Engineering School, Service School Command, Great Lakes and adapted for shipboard use by the Naval Education and Training Support Center, Pacific, San Diego. The Boiler Technicians also used materials covering the Engineering Operational Sequencing System. These were developed under a work agreement with the Naval Instructional Technology Development Center, San Diego, who awarded a subcontract to Manpower Development Services, Evanston, Illinois.

Appreciation is expressed to the following commands and their staffs:

- Commander Fleet Training Center, San Diego, for making available the facilities of the Individualized Learning Center.
- Commanding Officer, Recruit Training Command, Naval Training Center, San Diego, for help in the validation of the Engineering Operational Sequencing System Test.
- Director, Propulsion Engineering School, Service School Command, Great Lakes, Illinois, for help in the validation of the Basic Mechanical Procedures Test.
- Commander Naval Surface Force, Pacific Fleet; Commander Cruiser Destroyer Groups 3 and 5; and Commander Destroyer Squadrons 7, 9, 17, and 31 for allowing their ships to participate in the program on a volunteer basis.

Special appreciation is expressed to the Commanding Officers, Engineering Officers, and Boiler Technicians of the 13 cruisers and destroyers who volunteered to participate in the testing program.

Finally, the substantial and valuable assistance of the following persons is gratefully acknowledged: Ray E. Main for developing the behavioral objectives and test items of the Engineering Operational Sequencing System Module, Carolyn McLandrich for writing a computer program used in scoring the test, Robert C. Panell for analyzing the data, and BTC Danny L. Bowers and MMC Jon Hall for writing test items.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

The Personnel Readiness Training Program is concerned with the feasibility of using a diagnostic testing/shipboard training system to improve the readiness levels of Fleet personnel. In such a system, performance-oriented tests are used to diagnose deficiencies in job performance and shipboard self-instructional materials are individually prescribed to correct deficiencies revealed by the diagnostic tests. To obtain information on how and where this type of system might work, testing and training programs were developed for three applications: (1) the submarine Sonar Technician (ST) operating the AN/BQR-20A, (2) the submarine Missile Technician (MT) maintaining the Missile Test and Readiness Equipment (MTRE Mk 7 Mod 2), and (3) the Boiler Technician (BT) operating and maintaining the 1200 PSI Steam Propulsion Plant.

Purpose

The purpose of the effort described in this report was to determine whether the testing and training programs developed for the BT application were instrumental in improving essential basic skills and knowledges that support the operation and maintenance of the 1200 PSI Steam Propulsion Plant.

Approach

Boiler Technicians from 12 cruisers and destroyers equipped with 1200 PSI Steam Propulsion Plants were given diagnostic pretests and, with the exception of one crew, retested 3 to 6 months later. Two multiple-choice tests were given: one was concerned with basic skills and knowledges required to support plant maintenance, and the other with basic skills and knowledges required to support plant operation. Both tests were based on job performance requirements. Three experimental groups, each consisting of the BTs from four ships, were used in the evaluation: a Control Group, a Diagnostic Feedback Group, and a Diagnostic Feedback + Training Group. Following the pretests, members of the Control Group were given feedback on their performance in terms of an overall percentage score. Members of the Diagnostic Feedback Group were provided with a list of their individual areas of weakness. Members of the Diagnostic Feedback + Training Group were provided with the same type of information as the Diagnostic Feedback Group, but they were also assigned specific remedial training materials covering their individual areas of weakness.

Findings

Diagnostic testing was successful in detecting deficiencies of Fleet personnel on skills and knowledges related to the operation and maintenance of the 1200 PSI Steam Propulsion Plant. In the pretest sample, only 17 of the 305 Boiler Technicians tested showed no weaknesses. Providing the Boiler Technicians with feedback resulted in a very small, but statistically significant, improvement in performance. However, there was little effect of remedial training because only 21 percent of the Boiler Technicians completed their assigned training materials. Secondary analyses suggested that, had the assigned training been completed, it would have improved performance. One of the reasons the training was not fully completed was the extensive time demands placed on fireroom personnel. Another reason the training was not fully completed may

have been the lack of adequate study facilities on board ship. The two ships that were asked to study the materials in shorebased classrooms completed the most training (61 percent of that assigned). Not only were these men removed from the work demands and distractions of the shipboard environment, but they were also provided with a place to study.

Conclusions

Diagnostic testing was successful in detecting deficiencies of Fleet personnel on written items related to basic skills and knowledges essential to the operation and maintenance of the 1200 PSI Steam Propulsion Plant. The data suggest that, had the assigned training been completed, it would have improved performance. Feedback on diagnosed weaknesses had a statistically significant effect but little practical meaning. It would appear that basic skills and knowledges can be better acquired through a formalized instructional program than solely through on-the-job experience.

In a shipboard training program for propulsion engineering personnel, the availability of study time appears to be a key factor, although an adverse study environment may also play a role. Virtually no assigned training was accomplished on board ship, while a substantial amount was completed at shore facilities.

Recommendations

To improve the proficiency level of the BT and other propulsion engineering personnel responsible for operating and maintaining the 1200 PSI Steam Propulsion Plant, it is recommended that:

1. The training package supporting plant operation (i.e., self instruction on the Engineering Operational Sequencing System) be added to the training package supporting plant maintenance currently installed at the Individualized Learning Centers of the Fleet Training Centers at San Diego and Norfolk.
2. Performance deficiencies be identified by administering the diagnostic test package to fireroom and engineroom personnel. Remedial training materials should be assigned by means of the procedures developed as part of this study. Arrangements should then be made to allow the use of the Individualized Learning Centers on a day-to-day basis so that required remedial training can be completed with minimal disruption of ongoing shipboard activity.

On the basis of the findings of this study, the use of individualized, self-instructional material on board ship is not recommended unless sufficient study time and an appropriate study environment can be made available.

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INTRODUCTION

Problem

The Personnel Readiness Training Program is concerned with the feasibility of using a diagnostic testing/shipboard training system to improve the readiness levels of Fleet personnel. In such a system, performance-oriented tests are used to diagnose deficiencies in job performance and shipboard self-instructional materials are individually prescribed to correct deficiencies revealed by the diagnostic tests.

Background

The degree to which critical job skills can be improved through a system of diagnostic testing and shipboard training may depend on the rating and/or the type of task involved. Therefore, to obtain information on how and where the system might work, testing and training programs were developed for three applications: (1) the submarine Sonar Technician (ST) operating the AN/BQR-20A, (2) the submarine Missile Technician (MT) maintaining the Missile Test and Readiness Equipment (MTRE Mk 7 Mod 2), and (3) the Boiler Technician (BT) operating and maintaining the 1200 PSI Steam Propulsion Plant. These ratings and equipments were chosen for program evaluation because they were critical to the missions of their ships and they contained a sufficient variety of operator and maintenance tasks to permit the results to be generalized to other areas. Additionally, there were indications that performance deficiencies might be present in these areas.

The first report in this series (Laabs, Main, Abrams, & Steinemann, Note 1) described the general approach and how it was being applied in the three areas. Subsequent reports (Laabs, Panell, & Pickering, 1977; Winchell, Panell, & Pickering, 1976) described the Personnel Readiness Training Program for the MT and ST. A final report will summarize findings and conclusions across all three applications.

Purpose

The 1200 PSI Steam Propulsion Plant is a high pressure steam plant that has been plagued with problems of unreliability caused, in part, by training deficiencies. Routine maintenance of this steam plant requires that the BT be well grounded in basic mechanical skills and knowledges; proper operation requires a thorough knowledge of the Engineering Operational Sequencing System (EOSS), a system of step-by-step operating procedures. Deficiencies in these essential skills and knowledges reduce personnel readiness that, in turn, reduces operational readiness, but such deficiencies can be overcome by training. It is important to distinguish these deficiencies from other factors, such as lack of spare parts, poor equipment design, and personnel shortages, which also reduce operational readiness. The problems caused by the latter factors cannot be overcome by training.

The purpose of the present effort was to determine whether the testing and training programs developed for the BT were instrumental in improving skills and knowledges that support the operation and maintenance of the 1200 PSI Steam Propulsion Plant.

METHOD

Experimental Design

Boiler Technician crews from 12 Pacific Fleet cruisers¹ and destroyers equipped with 1200 PSI Steam Propulsion Plants participated in the evaluation of the BT application of the Personnel Readiness Training Program. As depicted in the experimental design, shown in Table 1, three experimental groups, each consisting of BT crews from four ships, were used in the evaluation: a Control Group, a Diagnostic Feedback Group, and a Diagnostic Feedback + Training Group. Before assignment to experimental groups, sets of three ships were matched on the basis of ship type, expected time at sea, and BT crew size. From these four sets of three ships, one ship was assigned to each experimental group. Members of all three experimental groups were to be given a diagnostic pretest and retested approximately 3 to 6 months later. What happened to the BT crews during the interim depended upon the group to which they were assigned (see Table 1). Due to the adverse environment of the BT shipboard spaces, two of the crews who were assigned remedial training materials were asked to use study facilities ashore, and the other two to use spaces on board ship.

Table 1
Experimental Design Used in the BT Application of the
Personnel Readiness Training Program

Group	Experimental Conditions		
Control	Pretest with non-specific feedback	Usual Operations	Posttest
Diagnostic Feedback	Pretest with specific feedback on weaknesses	Usual Operations	Posttest
Diagnostic Feedback + Training	Pretest with specific feedback on weaknesses and remedial training assigned	Usual Operations Special Training Packages On Board or Ashore	Posttest

¹Three ships in the sample requested that, in addition to their BTs, their Machinist Mates (MMs) be tested. Because the performance of the MMs was very similiar to that of the BTs, they were included in the final sample. The MMs constituted only 17 percent of the final sample and, for ease of exposition, the sample is referred to as being comprised of BT crews.

Remedial Training Materials

Basic Mechanical Skills and Knowledges

In all applications of the Personnel Readiness Training Program, existing materials (such as task analyses, tests, or training materials) were used whenever possible. In the BT maintenance area, previously developed training materials could be used. The core curriculum of the Propulsion Engineering School, Service School Command, Great Lakes, covers the basic mechanical skills and knowledges essential for the routine maintenance of propulsion engineering plants. This core curriculum is not only completed by recruits who are designated to become BTs, but also by those designated to become Machinist Mates (MMs) and Enginemen (ENs). It consists of modularized, self-paced instruction, which makes it an ideal source for individually prescribed remedial instruction. Because the curriculum had been adapted for shipboard use by the Naval Education and Training Support Center, Pacific, it could be readily incorporated into the BT application. It also had been installed at the Individualized Learning Center, Fleet Training Center, San Diego, which enabled a comparison to be made between training conducted ashore and on board ship. This is especially important to the BT application because training at a shore installation is an obvious way of overcoming the adverse environment of the BT shipboard spaces.

A total of 13 core curriculum modules, ranging in topic from use of hand tools to oil pollution, support the maintenance of the steam propulsion plant. In addition, a 14th module on the Planned Maintenance System (PMS), was adapted for shipboard use from another part of the Propulsion Engineering School curriculum. It was included because PMS documents were used as part of the diagnostic test. As shown in Table 2, which lists the basic skills and knowledges modules that were used in the BT application, the estimated time to complete a module ranged from 1 hour for the shortest module (Module 13) to 6 hours for the longest modules (Modules 4 and 6).

Engineering Operational Sequencing System (EOSS)

The Engineering Operational Sequencing System (EOSS) is a set of documents that provide detailed operating procedures for the 1200 PSI Steam Propulsion Plant, this system, which is relatively new and complex, contains not only step-by-step procedures for operating the steam plant, but also plant and space status diagrams, preferred alignment diagrams, troubleshooting charts, and casualty control procedures. If it is understood and used correctly, it results in the safe steaming of the plant by all propulsion engineering personnel.

Under a work agreement with the Naval Instructional Technology Development Center, San Diego, instructional material on EOSS and a 10-minute motivational film on the value of EOSS were produced. The self-instructional materials, which were developed under subcontract to Manpower Development Services, Evanston, Illinois, included the following lessons: (1) Introduction to EOSS, (2) Engineering Operational Procedures, (3) Engineering Operational Casualty Control, and (4) Supervising and Managing EOSS. To complete these lessons, the BT was required to work with reproductions of EOSS documents bound in a sample EOSS book. The estimated time to complete each lesson was 2-1/2 hours.

Table 2

Estimated Amount of Study Time Required for Completion of
Modules Covering Basic Skills and Knowledges

Module	Title	Study Time (Hrs.)
1	Metal Fasteners, Hand Tools	2-1/2
2	Pipe, Tubing, Fittings	2
3	Packing, Gaskets, Insulation	2-1/2
4	Valves	6
5	Bearings, Lubrication	3-1/2
6	Pumps	6
7	Precision Measuring Instruments, Technical Manuals	5
8	Heat Properties, Heat Exchangers	3
9	Indicating Devices	3
10	Turbines, Couplings, Gears	4
11	Strainers (Lesson 1) ^a	2
12	Low Pressure Air System and Compressor	4
13	Oil Pollution	1
14	Planned Maintenance System	1-1/2

^aJust the first lesson was used because the remaining lessons concern oil purifiers and are only completed by Machinist Mates.

Diagnostic Tests

The MT and ST applications of the Personnel Readiness Training Program (Laabs, Panell, & Pickering, 1977; Winchell, Panell, & Pickering, 1976) relied primarily upon hands-on performance tests to diagnose deficiencies. It was planned to follow the same approach for BT operator tasks, while using a job-related written test for BT maintenance tasks (Laabs, Main, Abrams, & Steinemann, Note 1). Therefore, a hands-on performance test, which required a ship to operate its steam plant in an auxiliary mode and to set a new fireroom watch every hour until all watch teams had been observed, was constructed for administration on board ships in port. Unfortunately, permission could not be obtained to administer this hands-on test to the 12 ships in the sample because of extensive demands already placed on the ships. In fact, permission could not even be obtained to try out the test on a single ship. Consequently, the BT application had to be altered to provide for a written, performance-oriented test on steam plant operation.

Basic Mechanical Procedures Test

This diagnostic test contained 104 multiple-choice questions.² To ensure that the test would be job-related, descriptions were provided of hypothetical job situations, which were derived from known job requirements. Under each such description, questions were asked that required the demonstration of both skills (e.g., reading a simulated measuring instrument such as a micrometer) and knowledges (e.g., identifying components of equipments and their functions) that support the job and that are covered in the basic modules. Answering the questions involved many actions that simulated those occurring on the job, (e.g., identifying tools, reading measurement devices, recognizing equipment components, and interpreting charts, tables, and diagrams).

The test was developed in two stages. In the first stage, a pool of 186 test items was administered to 200 BTs who were students at the Propulsion Engineering School, Great Lakes. Half of them, representing the pretest group, were just entering the course, and the other half, representing the posttest group, had just completed the basic modules listed in Table 2. A random sample of 25 students from each group was designated as a cross-validation sample. Thus, an item analysis was completed using the responses of the remaining 75 students in each group. Those items for each module (for a total of 94) that maximally discriminated between the two groups were selected for inclusion in the diagnostic test. Next, a cutoff score (i.e., pass/fail criterion) for each module was established based on the performance of the group that had completed the core curriculum. These cutoff scores were used to classify the students in the cross-validation sample. That is, if a student attained a score that was equal to or above the cutoff score, he would be classified as being like a post-test group member. If he attained a score below the cutoff score, he would be classified as being like a pretest group member. When this classification was compared to actual group membership, there was substantial agreement for all but two modules.

²Six additional questions are available on the part of Module 11 concerning oil purifiers.

In the second stage, which was conducted to refine the test, a pool of 127 items (the 94 items previously selected plus 33 new items) was administered to 150 students at the Propulsion Engineering School, none of whom had participated in the first stage. As with the first group, half of the students were just entering the course and half had just completed the core curriculum. Again, 25 students from each group were selected at random as a cross-validation sample, and an item analysis was conducted on the responses of the remaining 50 students in each group. Those items for each module (for a total of 110) that maximally discriminated between the two groups were selected for inclusion in the final test. As before, cutoff scores for each module were used to classify members of the cross-validation sample and there was substantial agreement for all modules. These cutoff scores were used to assign modules to members of the Diagnostic Feedback + Training Group. For example, if the cutoff score for a certain module was 8 and a member of the group scored 5, he would be considered deficient in the topic covered by that module and be assigned to complete it. A more detailed description of the item analysis and criterion determination procedures can be found in Laabs and Panell, Note 2.

EOSS Test

This diagnostic test, which contained 28 multiple-choice questions, used the same format as the Basic Mechanical Procedures Test. That is, it was both job-related and performance-oriented, because it involved reading and interpreting EOSS documents that were reproduced in the test booklet.

The method used to develop the EOSS test was similar to that used to develop the Basic Mechanical Procedures Test; however, there were not sufficient personnel available to perform extensive cross validation. That is, a pool of test items was administered to 27 BTs from a destroyer who had completed the EOSS module and 33 students who had just finished the Fireman Apprentice Course at the Naval Training Center, San Diego.³ The performance of the two groups was compared, and those questions for each lesson that maximally discriminated between them were used to make up the test. Lesson cutoff scores were determined on the basis of the performance of the BTs who had completed the module. These cutoff scores were used to assign EOSS lessons to the Diagnostic Feedback + Training Group.

Procedures

Pretest

A total of 305 BTs participated in the pretesting, with 95 BTs assigned to the Control Group; 98, to the Diagnostic Feedback Group; and 112, to the Diagnostic Feedback + Training Group. To minimize demands on the participating ships, testing was conducted in a dockside van at San Diego and Long Beach by members of the research team. The BTs were tested in groups of 10.

³The 2-week Fireman Apprentice Course is attended, immediately after recruit training, by those BTs not sent to A School. Only one 40-minute lecture describing EOSS is given during the course.

Before the pretests were administered, the BTs were informed that the testing program was experimental in nature and that they would be retested during the next 3 to 6 months. They were not told, however, that there were three different groups involved. Depending upon the group to which they were assigned, each BT crew was told the type of feedback information they would receive following testing. For example, members of the Diagnostic Feedback + Training Group were told they would be given an outline of their deficiencies and an individualized prescription for remedial training. In addition, members of this group were shown the 10-minute motivational film related to the use of EOSS. The remaining groups were shown the film at posttest.

Control Group. Following the pretest, members of this group were given feedback on their test performance in terms of an overall percentage score. For example, a BT was told that his scores were 65 percent on the Basic Mechanical Procedures Test and 56 percent on the EOSS Test. Members of this group were not provided with any information concerning their specific deficiencies and they were not given suggestions or directions as to how they might correct their deficiencies.

Diagnostic Feedback Group. Following the pretest, members of this group were provided with an outline indicating their individual weaknesses. If a member of this group did not meet the cutoff score established for assignment of a module to members of the Diagnostic Feedback + Training Group, the topic of the module was listed as an area of weakness. For example, if a BT missed 4 or more questions from the set of 12 questions keyed to the module on pumps, he was informed he was weak in that area. As with the Control Group, members of this group were not provided with any training materials or information as to how their deficiencies might be corrected.

Diagnostic Feedback + Training Group. Following the pretest, members of this group were given the same type of feedback as was given to those in the Diagnostic Feedback Group; that is, a list of individual weaknesses. In addition, they were assigned specific modules covering their individual weaknesses. For example, if a BT missed 7 or more questions from the set of 17 questions keyed to the module on valves, he was informed he was weak in that area and was assigned to complete the module on valves at times convenient for him during the next 3 to 6 months. So that the modules could be reused, each BT was supplied with a notebook containing a list of his weaknesses and assignments, and providing space for him to insert his answers. A master list of modules assigned to each BT was provided to the Engineering Officer for monitoring training and maintaining a record of completed modules. To evaluate the effect of the study environment, two of the ships in this group were asked to have the assigned training materials completed on board; and the remaining two, to have them completed ashore. For the "ashore" ships, one was to send its BTs, on a day-to-day basis, to the Individualized Learning Center, Fleet Training Center, San Diego; and the other, to classrooms available at the Long Beach Naval Shipyard. Just when the training was to be accomplished was left up to the individual ship.

Posttest

The posttest administered to all groups was the same as the pretest. However, one control ship, with a crew size of 42, could not be posttested. In addition, 90 BTs were unavailable for posttesting due to discharge, transfer, or leave, thereby reducing the Control Group to 28; the Diagnostic Feedback

Group, to 76; and the Diagnostic Feedback + Training Group, to 74. The distribution of pay grades and the percentage of the final sample each represents are shown in Table 3.

Table 3
Percentage Distribution of Pay Grades in the Experimental Groups

Pay Grades	Diagnostic Feedback + Training Group (N = 74)	Diagnostic Feedback Group (N = 76)	Control Group (N = 28)	Total Sample (N = 178)
E-3 and below	45	45	50	46
E-4	40	42	43	42
E-5	15	13	7	12

RESULTS

Basic Mechanical Procedures Test

Reliability and Validity

Since the Basic Mechanical Procedures Test was scored with respect to predetermined cutoff points, it should be classified as a criterion-referenced test. Therefore, most standard measures of reliability and validity developed for norm-referenced tests do not apply (Popham & Husek, 1969). The procedures used to estimate the reliability and validity of the Basic Mechanical Procedures Test are outlined below and are described in more detail in Laabs and Panell, Note 2.

In a program where the purpose is to diagnose deficiencies and to assign training to remedy those deficiencies, test reliability can be viewed in terms of the consistency of the diagnostic decisions made at two different points in time. Since the Control Group received no special treatment (i.e., no specific feedback and/or training materials), their pre- and posttest scores on the basic modules provided data to estimate test-retest reliability. Table 4 shows the percent of agreement in diagnostic decisions based on these test scores. Even though 3 to 6 months passed between the two test administrations, the percent agreement in diagnostic decisions for the individual modules ranged from a high of 96 percent to a low of 71 percent.

The Basic Mechanical Procedures Test has both high face and content validity because the test questions were related to job situations that the BT is required to do routinely. Job experts were used to determine what information contained in the modules was needed for a given job and to write the appropriate test questions. The extensive use of charts, diagrams, and illustrations in presenting each job situation added to both the face and content validity.

A measure of validity was calculated during the development of the test. As indicated previously, for the items selected for a module, a cutoff score was established on the basis of scores attained by students who had completed the core curriculum. During test refinement, the cutoff was applied to the scores of a separate cross-validation sample of 25 students who had completed the modules and 25 who had not. Members of the cross-validation sample who achieved the cutoff score for a module were classified as not needing training; and those who did not, as needing training. This classification was then compared to actual group membership. As shown in Table 5, the percent agreement between actual group membership and group membership based on test scores for each of the basic modules ranged from a high of 92 percent to a low of 68 percent.

Deficiencies in the Basics

Table 6 shows that, of the 305 BTs pretested, about 10 percent showed no deficiencies (i.e., 30 BTs met or exceeded the cutoff score on all 14 modules), 2 percent failed to reach the cutoff score on any of the 14 modules, and about 50 percent needed to complete five or more modules. (In the final sample of 187 BTs, about 7 percent showed no deficiencies.)

Table 4

Reliability of Diagnostic Decisions for Two Administrations
of the Basic Mechanical Procedures Test--Control Group
(N = 28)

Module	Title	Percent Agreement
1	Metal Fasteners, Hand Tools	89
2	Pipe, Tubing, Fittings	86
3	Packing, Gaskets, Insulation	79
4	Valves	86
5	Bearings, Lubrication	71
6	Pumps	82
7	Precision Measuring Instruments, Technical Manuals	75
8	Heat Properties, Heat Exchangers	71
9	Indicating Devices	71
10	Turbines, Couplings, Gears	71
11	Strainers (Lesson 1)	96
12	Low Pressure Air System and Compressor	82
13	Oil Pollution	71
14	Planned Maintenance System	75

Table 5

Group Membership Determined by the Basic Mechanical Procedures Test
Cross-validated Against Actual Group Membership--Test Development Group
(N = 50)

Module	Title	Percent Agreement
1	Metal Fasteners, Hand Tools	88
2	Pipe, Tubing, Fittings	78
3	Packing, Gaskets, Insulation	68
4	Valves	86
5	Bearings, Lubrication	74
6	Pumps	92
7	Precision Measuring Instruments, Technical Manuals	86
8	Heat Properties, Heat Exchangers	72
9	Indicating Devices	78
10	Turbines, Couplings, Gears	80
11	Strainers (Lesson 1)	88
12	Low Pressure Air System and Compressor	88
13	Oil Pollution	86
14	Planned Maintenance System	90

Table 6

Percentage of BTs in the Pretest Sample Who Were Diagnosed
as Needing the Indicated Number of Basic Modules

Number of Modules Needed	Experimental Groups			
	Diagnostic Feedback + Training (N = 112)	Diagnostic Feedback (N = 98)	Control (N = 95)	Total (N = 305)
14	0	4	1	2
13	4	3	1	3
12	4	4	1	3
11	4	1	3	3
10	2	3	7	4
9	4	2	2	3
8	7	6	5	6
7	6	7	4	6
6	10	13	5	9
5	10	10	10	10
4	1	7	14	7
3	10	10	7	9
2	12	11	15	13
1	11	12	14	12
0	14	5	10	10

A separate analysis for each module was hindered because the great majority of the BTs in the Diagnostic Feedback + Training Group did not complete their assigned training (only 21 percent of these BTs completed the Basic Mechanical Procedures modules they were assigned). Thus, the main analysis involved the comparison of the total score achieved over all modules on the Basic Mechanical Procedures Test for each experimental group. Only those members of each group who failed to meet the cutoff scores for one or more of the modules were included in the analysis. The overall percent correct at pre- and posttest for the three experimental groups is shown in Table 7. This total score analysis had the effect of combining small changes in each of the 14 areas that might not be statistically significant when analyzed separately. An analysis of variance with repeated measures on the pre-/posttest variable indicated that (1) the overall average improvement of 3 percent was significant ($F(1, 160) = 14.92$, $p < .001$), and (2) there were differential score increases for the groups from pre- to posttest ($F(2, 160) = 6.22$, $p < .005$). Further analyses revealed small but significantly greater score increases for both the Diagnostic Feedback + Training Group and the Diagnostic Feedback Group than for the Control Group ($F(1, 160) = 35.35$, $p < .001$, $F(1, 160) = 10.72$, $p < .001$; respectively). The very small additional effect of training over that of feedback was not surprising in view of the extremely low completion rate. Separate analyses were performed on the data for the individual modules using only those members of each group who failed to meet the cutoff for each module. In general, the results of these analyses confirmed that the changes due to training and/or feedback were too small to be statistically significant when observed for the separate modules.

Table 7

Overall Percent Correct on the Basic Mechanical Procedures Test
at Pre- and Posttest for Three Experimental Groups

Condition	Groups		
	Diagnostic Feedback + Training (N = 70)	Diagnostic Feedback (N = 70)	Control (N = 23)
Pretest	70	72	73
Posttest	76	75	72

Note. BTs who exceeded cutoff on all modules are not included.

EOSS Test

Reliability and Validity

The multiple-choice EOSS Test was designed to diagnose deficiencies in the use and knowledge of EOSS so that training could be assigned to remedy those deficiencies. Using the same procedure followed with the Basic Mechanical Procedures Test, the reliability of the EOSS Test was estimated in terms of the consistency of the diagnostic decisions. For the EOSS Introduction lesson, there was 79 percent agreement in diagnostic decisions from pre- to posttest; for the Engineering Operational Procedure lesson, 64 percent; for the Engineering Operational Casualty Control lesson, 61 percent; and for the EOSS Supervision and Management lesson, 61 percent.

The EOSS Test was developed in a manner similar to that used with the Basic Mechanical Procedures Test. It has both high face and content validity because of extensive use of reproduced EOSS material and because the questions were based upon actual job requirements. To answer test questions, the BTs had to refer to EOSS diagrams, charts, and tables that would be used on the job. Unfortunately, there was not a sufficient number of BTs available during the development of this test to cross-validate it, as was done in the development of the Basic Mechanical Procedures Test.

Use and Knowledge of EOSS

Table 8 shows that, of the 305 BTs in the pretest sample, about 65 percent failed to reach the cutoff score on one or more of the EOSS lessons and about 35 percent showed no deficiencies. (In the final sample of 187 BTs, about 28 percent showed no deficiencies.)

Table 8

Percentage of BTs in the Pretest Sample Who Were Diagnosed
as Needing the Indicated Number of EOSS Lessons

Number of Lessons Needed	Experimental Groups			
	Diagnostic Feedback + Training (N = 112)	Diagnostic Feedback (N = 98)	Control (N = 95)	Total (N = 305)
4	5	3	2	4
3	18	14	14	15
2	21	23	26	24
1	20	28	18	22
0	36	31	40	35

The data were analyzed for the EOSS Module as a whole. That is, those members of each group who failed to meet the cutoff score for one or more of the four lessons of the module were included in the analysis. The overall percent correct at pre- and posttest for the three experimental groups is shown in Table 9. An analyses of variance with repeated measures on the pre-/posttest variable indicated that the overall average improvement of about 4 percent was significant ($F(1, 51) = 8.40, p < .01$). No other effect was found to be significant.

Table 9

Overall Percent Correct on the EOSS Test
at Pre- and Posttest for Three Experimental Groups

	Groups		
	Diagnostic Feedback + Training (N = 48)	Diagnostic Feedback (N = 59)	Control (N = 19)
Pretest	42	44	40
Posttest	48	47	45

Note. BTs who exceeded cutoff on all lessons are not included.

DISCUSSION

Skills and Knowledges Deficiencies

The pretest results showed that there were many deficiencies in answering sets of performance-oriented, written items related to the operation and maintenance of the 1200 PSI Steam Propulsion Plant. The seriousness of the problem is indicated by the fact that the test only covered basic skills and knowledges that were considered to be essential for proper operation and maintenance of the steam propulsion plant. Only 6 percent of the pretest sample, which was composed of Pay Grades E-5 and below, showed no deficiencies.

An examination of the effect of previous school experience on performance on the Basic Mechanical Procedures Test revealed that the BTs who had attended A School failed fewer modules (4.1) than those who had not (8.3). For those BTs who had attended A School, it made little difference whether or not they had attended before or after the school instituted the current self-paced instructional program. Further, there was no effect of school experience on performance on the EOSS Test. This might be expected because the EOSS Module was developed especially for the present program and not adapted from the A School curriculum as were the other 14 modules.

The results from the 11 BT crews retested showed that the performance of all three experimental groups improved a very small, but significant, amount from pre- to posttest on their total scores for the Basic Mechanical Procedures Test. However, both groups that received feedback showed more improvement than the Control Group. Although this differential improvement was statistically significant, it should be recognized that it was so small as to have little practical meaning. In general, there was no differential group improvement when the 15 modules (including the EOSS Module) were analyzed separately.

Lack of a Training Effect

Since the great majority of BTs in the Diagnostic Feedback + Training Group did not complete their assigned modules, it is not surprising that there was little evidence of improvement due to training. Because of the extremely low completion rate for all 15 of the modules (only 21 percent of the BTs completed their assigned modules), it was not clear whether better posttest scores would have been attained if the modules assigned had been completed. Therefore, the scores of those BTs who had completed a given module were compared with those of similar BTs from the other two groups. That is, members of the Control Group and Diagnostic Feedback Group who would have been assigned that same module were selected to form a yoked subsample for that module. Unfortunately, yoked subsamples of even marginal size could not be formed for most of the modules. Only the data from the six modules for which nine or more BTs completed their assigned training were analyzed. Table 10 shows the percentage score at pre- and posttest for the six yoked subsamples under each experimental condition. In four of the six cases, there was a differential increase in score from pre- to posttest, as indicated by the significant statistical interactions. In each of these cases, the score increase for the Diagnostic Feedback + Training Group was significantly greater than that of the other two groups, as indicated by the test of simple main effects shown in Table 11. In addition, the differential score increase approached significance for one of the remaining two modules, Module 5 ($F(2, 32) = 3.0$, needed 3.30 for $p < .05$), with the Diagnostic Feedback + Training Group again showing a bigger increase than the other two groups.

Table 11
F Values for Tests of Simple Main Effects Between Pre- and Posttest
when there was a Significant Statistical Interaction

Experimental Group	Module				
	1 (df = 27)	2	3 (df = 2)	5	7 (df = 30)
Diagnostic Feedback + Training (df = 1)	19.89**		18.99**		32.43**
Diagnostic Feedback (df = 1)	1.74	Interaction Not Significant	.53	Interaction Not Significant	2.03
Control (df = 1)	.27		1.20		.30
					1.58
					5.04*

* $p < .05$
** $p < .01$

Table 10
Percent Correct for Yoked Subsamples with Associated F Values of Analyses of Variance

Module	Title	Experimental Conditions						F Values		
		Diagnostic Feedback + Training		Diagnostic Feedback		Control		Group Effect(df)	Pre/Post Effect(df)	Group X Pre/Post Interaction(df)
		Pre	Post	Pre	Post	Pre	Post			
1	Metal Fasteners, Hand Tools	65	86	65	71	66	68	N.S.	13.1**(1,27)	4.3*(2,27)
2	Pipe, Tubing, Fittings	25	48	27	43	25	47	N.S.	22.0**(1,23)	N.S.
3	Packing, Gaskets, Insulation	29	69	29	35	28	40	N.S.	12.1**(1,22)	3.5*(2,22)
5	Bearings, Lubrication	30	57	34	42	30	42	N.S.	19.6**(1,32)	N.S.
7	Precision Measuring Instruments, Technical Manuals	51	73	46	50	40	42	6.6**(2,30)	15.1**(2,30)	5.7**(2,30)
15	Engineering Operational Sequencing System	38	49	36	39	40	34	N.S.	N.S.	3.1*(2,33)

* $p < .05$

** $p < .01$

While the above comparisons are based on very small subsamples, they do suggest, that had training been completed, it would have improved performance. Additional support on this point was obtained from an analysis of the Basic Mechanical Procedures Test scores for the BT crew that had completed the greatest percentage of assigned modules. This crew's completion rate was 79 percent as compared to an average rate of 15 percent for the other three training crews. Its improvement rate was 23 percent as compared to 6 percent for the other three training crews.

On the Role of Study Time and Environment

There are two evident reasons for the nonuse of training materials: (1) the lack of time to complete training on board ship, and (2) the poor study environment on board ship. One ship in the Diagnostic Feedback + Training Group reported that, for a 2-month period, it spent approximately 85 percent of its time at sea with engineering personnel standing port and starboard watches (i.e., a continuous sequence of 6 hours on watch followed by 6 hours off). As might be expected, this ship completed the least amount of assigned training (only 1 percent of that assigned). The other ship that was asked to study instructional materials on board ship completed only 10 percent of the training assigned. To add to the burden of normal operations, both of these ships were preparing for inspections by the Mobile Training Team and the Propulsion Examination Board. In addition to the heavy work load, the adverse conditions in the BT work spaces are not conducive to the study of training materials.

The two ships asked to study instructional materials on shore completed 61 percent of the assigned training while the other two ships completed only 5 percent. The completion rate of the ship that used shipyard classrooms (46 percent of the training assigned) would have been much higher if it had not been for an overzealous training supervisor who decided that his crew should complete all the modules. Savings in training time, which should have resulted from the individualized remediation, were not realized because everyone was started on Module 1 and proceeded sequentially. As might be expected, most of the earlier modules assigned were completed, but very few of the later ones. However, the total amount of time spent on studying the modules was approximately that required to complete just those modules diagnosed as needed. The best completion rate (79 percent of the training assigned) was logged by the ship that was asked to study instructional materials at the Individualized Learning Center, Fleet Training Center, San Diego.

Supplementary Material Costs

A large portion of the present program's training material is currently available for use either on board ship or at the Individualized Learning Centers of the Fleet Training Centers at San Diego and Norfolk.⁴ Therefore, the cost associated with implementing the present testing-and-training program is limited mainly to obtaining supplementary materials as outlined on the following page.

⁴Additional copies of the 13 basic modules can be obtained from the Naval Publications and Forms Center, Philadelphia (NAVEDTRA 7500, Stock Number 0502-LP0375000).

In lots of 300, the cost of adding the Basic Mechanical Procedures Test to the 13 basic modules is estimated at less than \$1.00 per set. The additional cost of expanding this set of modules to include Module 14 and 15 (including the EOSS Test) is estimated at approximately \$5.00 per set. The cost per set would increase if the modules and diagnostic tests were only integrated into the program available at the Individualized Learning Centers of the Fleet Training Centers at San Diego and Norfolk. In lots of 50, the cost per set is estimated at approximately \$25.00. Table 12 provides a breakdown of estimated cost by material and lot size.

Table 12
Estimated Cost of Testing and Training Materials

Materials	Components	Estimated Cost Per Copy	
		50 Lot	300 Lot
Module 14 (Planned Maintenance System)	52 Printed Pages 2 Foldouts	\$ 3.74	\$1.25
Module 15 (Engineering Operational Sequencing System--EOSS)	120 Printed Pages 4 Separate Lessons	\$10.40	\$3.48
Sample EOSS Book	129 Printed Pages 20 Binders 1 Binder	\$ 8.00	\$2.67
EOSS Test	16 Printed Pages 1 Assignment Guide	\$ 1.56	\$.25
Basic Mechanical Procedures Test	42 Printed Pages 1 Assignment Guide	\$.76	\$.52

CONCLUSIONS

Diagnostic testing was successful in detecting deficiencies of Fleet personnel on written items related to basic skills and knowledges essential to the operation and maintenance of the 1200 PSI Steam Propulsion Plant. The data suggest that, had the assigned training been completed, it would have improved performance. Feedback on diagnosed weaknesses had a statistically significant effect but little practical meaning. It would appear that basic skills and knowledges can be better acquired through a formalized instructional program than solely through on-the-job experience.

In a shipboard training program for propulsion engineering personnel, the availability of study time appears to be a key factor, although an adverse study environment may also play a role. Virtually no assigned training was accomplished on board ship, while a substantial amount was completed at shore facilities.

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RECOMMENDATIONS

To improve the proficiency level of the BT and other propulsion engineering personnel responsible for operating and maintaining the 1200 PSI Steam Propulsion Plant, it is recommended that:

1. The training package supporting plant operation (i.e., self instruction on the Engineering Operational Sequencing System) be added to the training package supporting plant maintenance currently installed at the Individualized Learning Centers of the Fleet Training Centers at San Diego and Norfolk.

2. Performance deficiencies be identified by administering the diagnostic test package to fireroom and engineroom personnel. Remedial training materials should be assigned by means of the procedures developed as part of this study. Arrangements should then be made to allow the use of the Individualized Learning Centers on a day-to-day basis so that required remedial training can be completed with minimal disruption of ongoing shipboard activity.

On the basis of the findings of this report, the use of individualized, self-instructional material on board ship is not recommended, unless sufficient study time and an appropriate study environment can be made available.

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